CHAPTER 2

CONSTRUCTION METHODS AND MATERIALS: ELECTRICAL AND MECHANICAL SYSTEMS

The responsibility for the design of electrical and mechanical systems rests with the engineering officer. However, as an EA assisting the engineering officer, you should be familiar with the methods, materials, and terminology used in the design and construction of these systems. This chapter provides that familiarity.

This chapter expands on the EA3 TRAMAN discussion of exterior electrical distribution systems. You should find it helpful to review chapter 9 of that TRAMAN before beginning the study of the following text.

This chapter also discusses water distribution and sewage collection systems that are exterior to buildings. You will find that some of the materials and terminology used in the design and construction of these systems are the same as those used for building plumbing. Therefore, you also should find it helpful to review chapter 8 of *Engineering Aid 3.*

ELECTRICAL POWER SYSTEM

Overall, an electrical power system includes the electrical lines, or circuits, and all of the associated equipment that are necessary to supply power from a generation point to the users of the supplied power. Generally, the power system is considered to consist of two parts: the **transmission system** and the **distribution system.** Figure 2-1 shows a typical electrical power

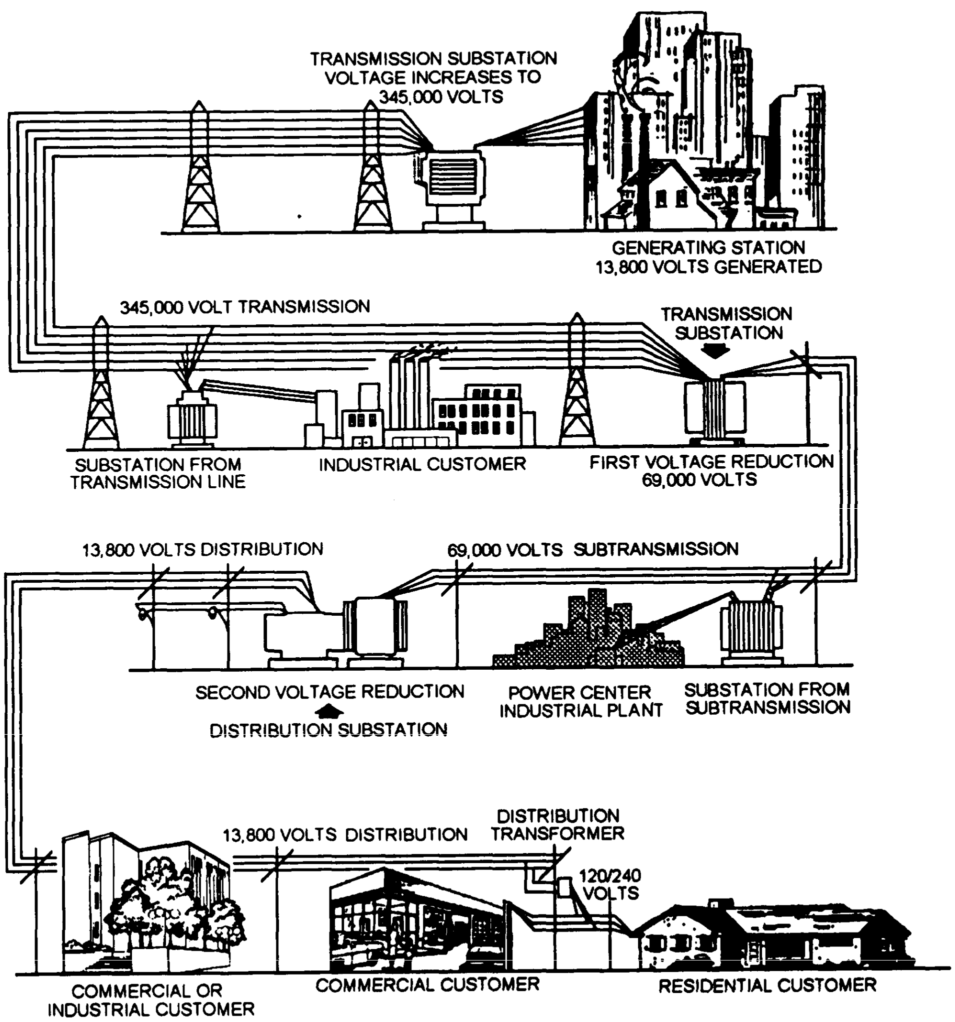

Figure 2-1.—Typical electrical power system.

system that includes both the transmission and distribution systems. To explain the two systems, we will begin with the transmission system.

TRANSMISSION SYSTEM

Refering to figure 2-1, you will see that the starting point for electrical power is its place of generation, or **generating station,** which uses fossil fuels, water pressure, or, in some locations, nuclear energy to drive turbine generators. The energy generated in these stations is generally in the range of 13,200 to 24,000 volts. That voltage is insufficient for economical transmission over long distances. Therefore, the voltage is raised to transmission levels of 138,000 to 765,000 volts at a **transmission substation** located at the generating station. A substation is a facility that contains transformers, switches, and other equipment that is used to raise or lower voltages to transmission or distribution levels and to protect the substation and the transmission lines or distribution feeders against faults.

Sets of conductors that are energized with high voltage and transmit large bulks of power over relatively long distances are known as **transmission lines** or **transmission circuits.** Usually, these circuits are run overhead with structures supporting the conductors, which are attached to insulators. In some locations where it is not practical or permissible to have overhead high-voltage lines, the transmission lines may be run underground. The transmission lines shown in figure 2-1 are overhead and supported by towers.

As shown in the figure, the transmission lines, or circuits, deliver power from the **transmission substation** located at the generating plant to customers located along the route. Where required throughout its length, transmission circuits are equipped with additional transmission substations that lower the voltage to reduced transmission (or subtransmission) levels. The transmission circuits are also equipped with **distribution substations** that reduce the voltage to required distribution levels. It is at the distribution substations that the distribution system begins.

DISTRIBUTION SYSTEM

The distribution system is that portion of the electrical power system that connects the transmission system to the user's equipment. It includes distribution substations, feeder circuits, distribution centers, primary mains, distribution transformers, protective devices, secondary circuits, and services. Figure 2-2 shows the principal elements of a distribution system.

A power distribution system may be either an overhead distribution line or an underground cable

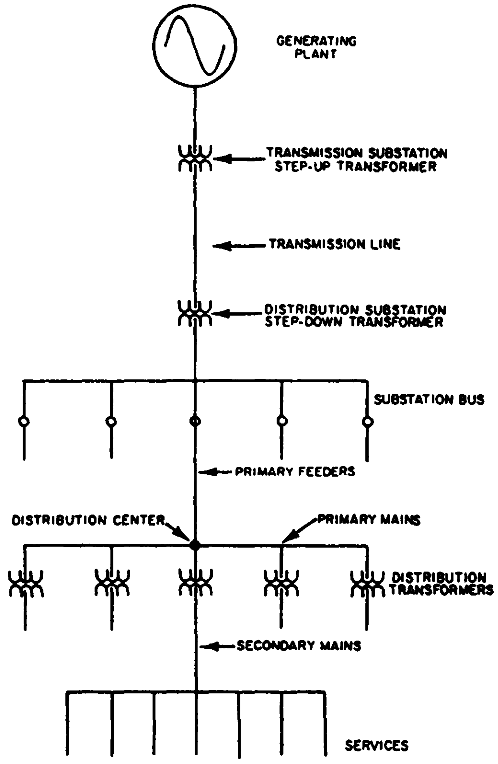

Figure 2-2.—Elements of a power distribution system.

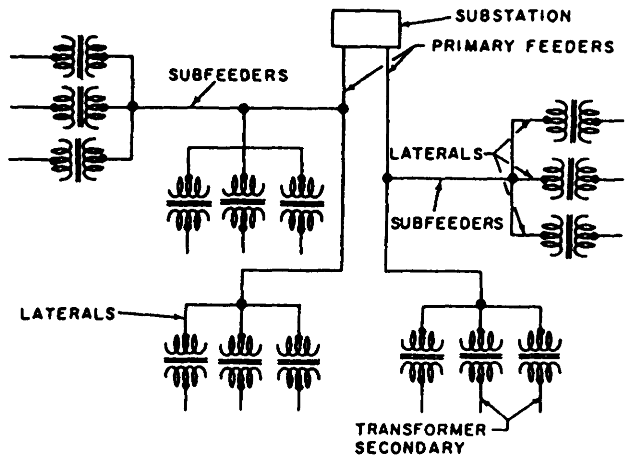

Figure 2-3.—Radial distribution system.

system. Since it is less costly to construct, the overhead system is more common. However, in some instances, such as near an airfield, an underground system may be required. This chapter will discuss mainly the overhead distribution system.

Substations

The distribution substation transforms the transmission voltage to the proper distribution voltage levels and protects the substation and transmission lines against faults occurring in the feeder circuits. At advanced bases, the source of power may be generators

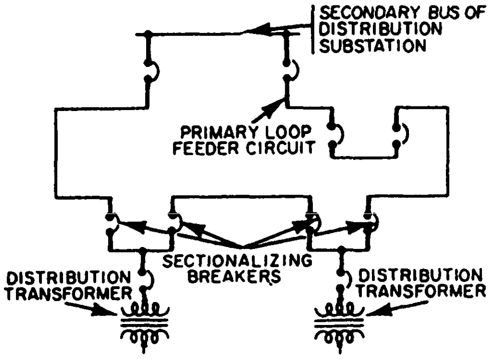

Figure 2-4.—Loop (or ring) distribution system.

connected directly to distribution centers. This eliminates the need for substations because the generator generates a usable voltage.

Primary Feeders

Primary feeders are those conductors in a distribution system that are connected from the distribution substations and that transfer power to the distribution centers (fig. 2-2). They may be arranged as radial, loop, or network systems and may be overhead or underground.

RADIAL DISTRIBUTION SYSTEM.— A schematic example of a radial distribution system is shown in figure 2-3. In this system, primary feeders take power from the distribution substation to the load areas by way of subfeeders and lateral-branch circuits. This is the most common system used because it is the simplest and least expensive to build. It is not the most reliable system, however, because a fault or short circuit in a main feeder may result in a power outage to all the users served by the system.

Service on this type of system can be improved by installing automatic circuit breakers that will reclose the service at predetermined intervals. If the fault continues after a predetermined number of closures, the breaker will be locked out until the fault is cleared and service is restored.

PRIMARY LOOP (OR RING) DISTRIBUTION SYSTEM.— The loop (or ring) distribution system is one that starts at a distribution substation, runs through or around an area serving one or more distribution transformers or load centers, and returns to the same substation. The loop system (fig. 2-4) is more expensive to build than the radial type, but it is more reliable and may be justified in areas where continuity of service is required—at a medical center, for example.

In the loop system, circuit breakers sectionalize the loop on both sides of each distribution transformer connected to the loop. A fault in the primary loop is cleared by the breakers in the loop nearest the fault, and power is supplied the other way around the loop without interruption to most of the connected loads. If a fault occurs in a section adjacent to the distribution substation, the entire load can be fed from one direction over one side of the loop until repairs are made.

NETWORK SYSTEM.— The network system (fig. 2-5) is the most flexible type of primary feeder

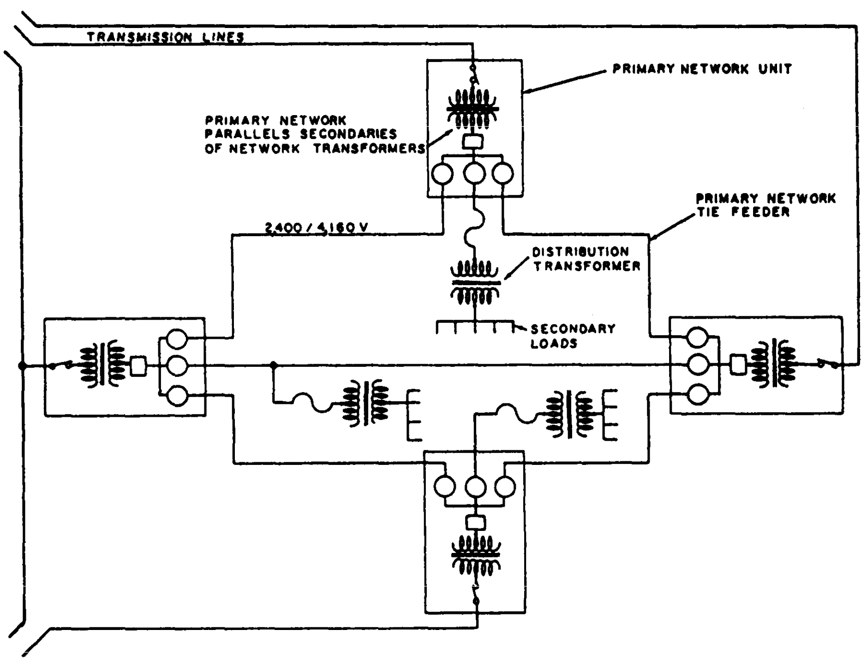

Figure 2-5.—Network distribution system.

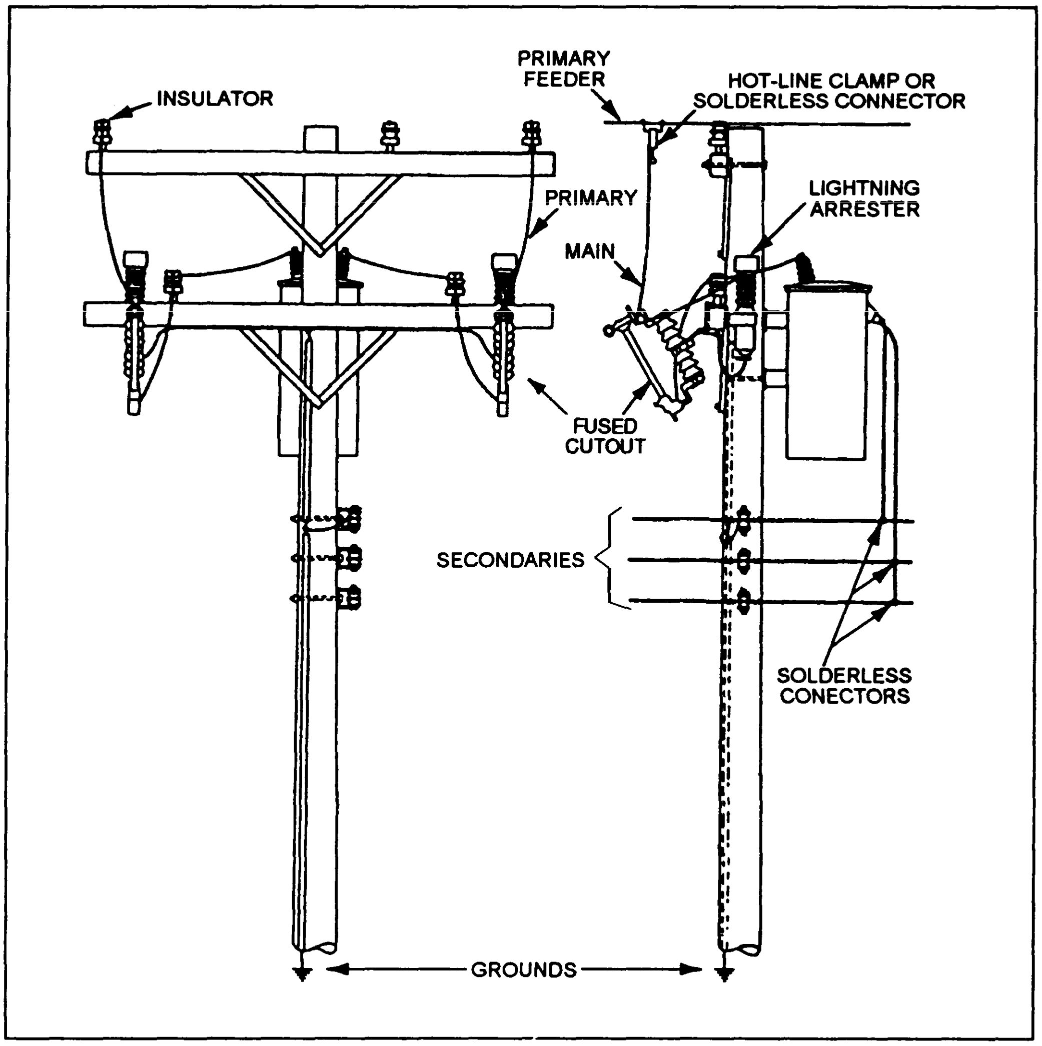

Figure 2-6.—Typical pole-mounted feeders, primary mains, transformers, and secondaries.

system. It provides the best service reliability to the distribution transformers or load centers, particularly when the system is supplied from two or more distribution substations. Power can flow from any substation to any distribution transformer or load center in the network system. The network system is more flexible about load growth than the radial or loop system. Service can readily be extended to additional points of usage with relatively small amounts of new construction. The network system, however, requires large quantities of equipment and is, therefore, more expensive than the radial system.

Primary Mains

Primary mains are connected to the primary feeders. In overhead installations, these mains are always installed below the feeders on a pole. The distribution transformers are connected to the primary mains through fused or automatic cutouts. Figure 2-6 shows the primary main to which the transformer is tapped. The cutouts, one on each primary line, contain the fuses that protect the transformer against overload and short circuits.

Distribution Transformers

Most electrical equipment in the Navy uses 120/208 volts. The primary voltage on Navy shore installations, however, is usually 2,400/4, 160 volts. For this reason, a **distribution transformer** is required to reduce (step down) the high primary voltage to the utilization voltage of 120/208 volts. Figure 2-6 shows one of various different types of transformer arrangements and installations. Regardless of the type of installation or arrangement, transformers must be protected by fuses or circuit breakers and lightning protection.

There are three general types of single-phase distribution transformers. The conventional type (fig. 2-6) requires a lightning arrester and fused cutout on the primary phase conductor feeding it. The self-protected (SP) type has a built-in lightning protector. The completely self-protected (CSP) type has the lightning arrester and current-overload devices connected to the transformer. It requires no separate protective devices.

Secondary Mains

Secondary mains or circuits are the lines that carry the electric power from the secondary side of the transformer through a distribution system to supply the electrical loads. They may or may not be on the same pole with the feeder lines. If on the same pole, they may be either on a crossarm below the feeder lines or, as shown in figure 2-6, on spool racks attached to the side of the pole below the feeder lines. The secondary circuits may have several wires (service drops) connected to various buildings to serve their electrical needs. Where a large load is in demand, a transformer or transformer bank may be located at the building site.

SINGLE PHASE.— Single-phase secondary circuits usually supply current for electrical lighting loads, small electric appliances, and small (1 horsepower and under) single-phase electric motors. The secondaries consist of two hot conductors and one neutral conductor. In overhead construction, these conductors are mounted on the bottom crossarm on a pole or on spools attached to the side of a pole. (See fig. 2-6.) One transformer will feed this circuit if the required load to be served is not too heavy. Where the load is heavy or where several buildings are served, a bank of three transformers may feed the circuit.

The normal voltage of a single-phase circuit is 120 volts from either one of the energized conductors to the neutral or 240 volts across the two energized conductors.

THREE PHASE.— Some facilities, such as motor pools, industrial shops, and water and sewage plants, may have equipment using three-phase motors, which require three-phase power. Transformer banks are installed to supply this power. If a number of buildings in the area require three-phase power, cluster mount may be installed with the three-phase secondaries extending in two or three directions and with service drops extending from the secondary to the buildings.

Service Drops

As you learned in the EA3 TRAMAN, each building requiring electric current must have lead-in conductors, known as **service drops.** These may be two-, three-, or four-wire conductors or a single cable containing the required number of conductors. A service drop may be connected to a secondary main to provide service to a small load. Where a transformer bank services a building requiring a large power load, the secondary becomes the service drop, since it feeds current to one load only.

Most Navy buildings are not metered. However, where it is desired to know how much electricity is being consumed, a meter is installed ahead of the main switch to the building. In this case, the service drop is connected to the meter before it is connected to the mains.

CONTROL AND PROTECTIVE DEVICES

A power-distribution circuit, like any other electrical circuit, requires the use of special devices to provide control and to protect the system from internal or external influences that may damage the circuit or injure personnel.

Distribution Cutouts, Switches, Reclosers, and Circuit Breakers

A distribution cutout is used to protect the distribution system or the equipment connected to it. Distribution cutouts are used with the installation of transformers (fig. 2-6), capacitors, cable circuits, and at sectionalizing points on overhead circuits.

Two types of switches used in power distribution are the air switch and the oil switch. Both devices are used to connect or disconnect a portion of the power distribution system. The air switch is used for the overhead section of the distribution system, and the oil switch is used with underground portions.

Reclosers are for overload protection and are designed to open a circuit in an overload condition and then automatically reclose the circuit. Reclosers come in single-or three-phase models and can either be pole mounted or installed in a substation.

Oil, air, gas, and vacuum circuit breakers are used to switch electric circuits and equipment in and out of the system. They may be operated manually, by remote control, or automatically under predetermined conditions or when electrical failures in the system occur.

Lightning Arresters

The purpose of installing a lightning arrester (fig. 2-6) on primary lines is twofold: first, to provide a point in the circuit at which a lightning impulse can pass to earth, through a ground wire, without injuring line insulators, transformers, or other connected equipment;

and second to prevent any follow-up power current from flowing to ground Lightning arresters must be installed on the primary side of all substations, distribution centers, distribution transformers, and capacitor banks.

CONDUCTOR SUPPORTS

An important element in any overhead electrical distribution system is a structure that is designed to support the weight of the conductors and all equipment mounted on the structure. The structure is also designed to provide required clearances from the ground to the conductors and between conductors. Common types of structures used for this purpose are wood poles, reinforced concrete poles, metal poles, and metal towers. The following text discusses poles.

Types of Poles

Poles used in the Navy can be wood, reinforced concrete, or metal (steel or aluminum). However, concrete and metal poles should be used only when they are more economical or when special considerations warrant their use.

WOODEN POLES.— Wood poles are available in various types, depending upon species of trees available in the area. For example, yellow pine is commonly used in the eastern United States. The length and circumference of poles also vary. Poles are available in 5-foot incremental lengths and with top circumferences varying in 2-inch increments. Therefore, we have poles that measure 30, 35, 40 feet, and so on, in length and 17, 19, 21 inches, and so on in top circumference.

The classification (or **class)** to which a wood pole, of given length and top circumference, belongs is determined from the circumference of the pole measured at a point 6 feet up from the butt. The class determines the strength of the pole, which is the ability of a pole to resist loads applied 2 feet from the top of the pole. Pole classes are numbered from 1 to 10, with 1 being the strongest. A Class 2 pole, for example, will withstand a force of 3,700 pounds and a Class 4 pole will withstand 2,400) pounds of force.

Wood poles are used mostly in distribution systems and light-duty transmission lines. The class of pole used depends on what the pole is used for. In other words, is the pole to be used as a line pole, corner pole, or transformer pole? The length of pole used is determined, in part, by the clearances required for the voltage of the circuits on the poles, the number of circuits, and the location of the pole in relation to streets, railroads, buildings, and so forth. Clearances are also required to provide safe working conditions for linemen working on the lines. All clearances have minimum requirements that are set by the American National Standards Institute (ANSI) and the National Fire Protection Association (NFPA). These requirements are specified in the *National Electrical Safety Code* (NESC), ANSI C2-87, and the most recent edition of the *National Electrical* Code®(NEC®).

Engineers also consider local conditions when determining the length of poles. For example, poles located in densely popular high-traffic areas need to be higher than those located in sparsely populated rural areas. In the Navy, the MINIMUM height of a wooden transformer pole is 35 feet and of all other wood poles, 30 feet. Other guidance regarding the heights and classes of poles is found in *Power Distribution Systems,* MIL-HDBK-1004/2.

CONCRETE POLES.— Concrete poles are preferred where the life of wood poles is shortened by local conditions. Concrete poles may be solid or hollow. Solid concrete poles are made in a trough form with steel reinforcing rods running lengthwise. The hollow type of pole is made by placing the concrete and reinforcing rods into a cylinder of the desired length and taper and then revolving the cylinder in a lathelike machine. The hollow type is lighter than the solid type and, in addition, provides a means for making connections through the pole to underground cables or services. This technique allows wires to be concealed from view and protected from the weather.

The exterior form of concrete poles can be changed to meet almost any need. Gains (cut notches) for crossarms and holes for bolts are cast in the pole. Either metal pole steps are solidly cast into the pole or prethreaded holes for the steps are installed.

Although concrete poles last longer and are stronger than wood poles, they are also expensive to make and install. However, the rising cost of wood poles and their treatment and maintenance plus better landscaping have brought on an increased use of concrete poles.

METAL POLES.— Metal poles used in the Navy are either steel or aluminum. Steel poles are not used in ordinary power-line distribution circuits except for unusual circumstances, such as where there is a high stress or heavy load placed on the pole. Aluminum poles are used for lightweight distribution, such as street-lights.

Guying of Poles

As poles must be strengthened sufficiently to carry heavy conductors and pole-mounted equipment, the

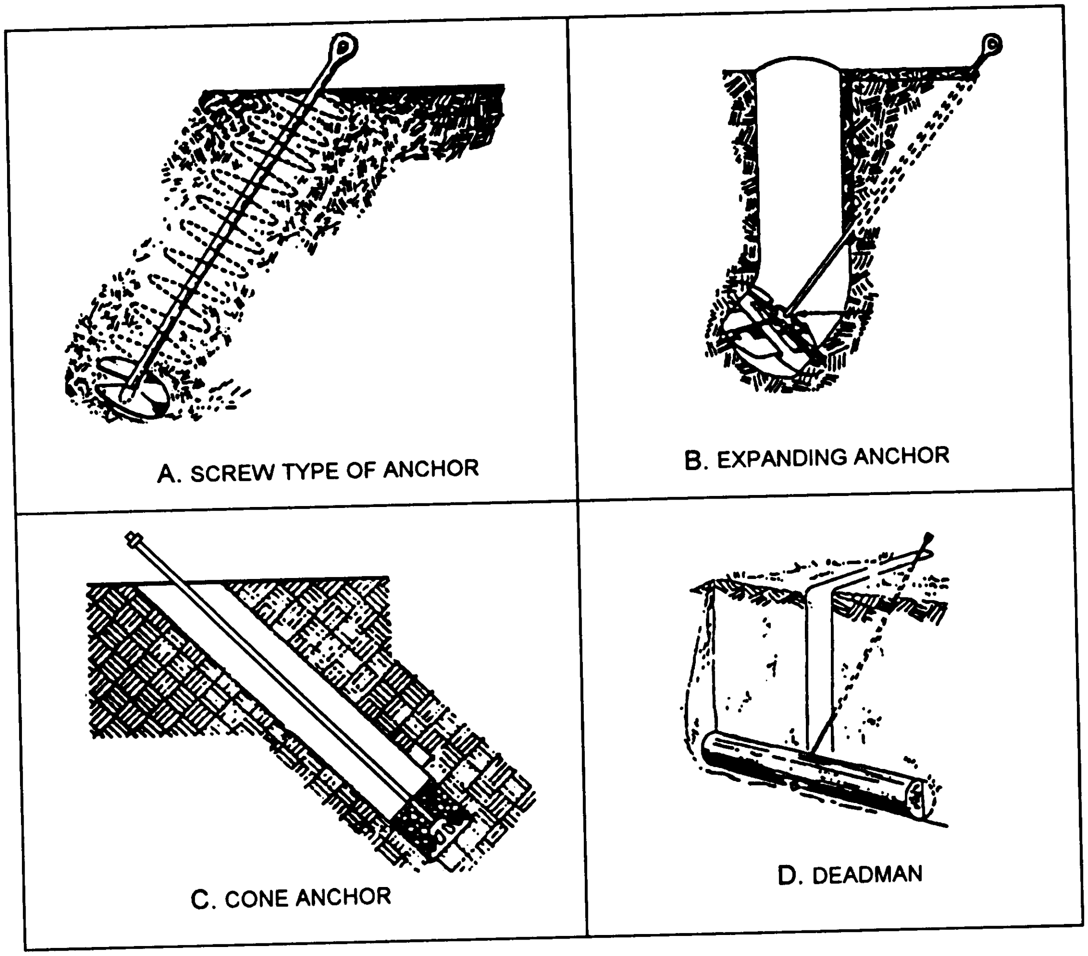

Figure 2-7.—Anchors.

proper anchoring and guying of pole lines is essential. These precautions also help to support poles that are set in sandy or swampy ground, and they counteract added strains caused by the elements, such as high winds, snow, and ice.

Various types of guy anchors have been developed to hold imposed loads securely in varying soil conditions. Some of these types are shown in figure 2-7.

There are many different uses of guys, some of which are shown in figures 2-8 through 2-13. Each usage has its own terminology as follows:

1. DOWN GUYS. The most common type of guy is the down guy. With this type of guy, the wire is run from the top of the pole to an anchor in the ground. Some common uses of the down guys areas follows:

a. SIDE GUY. A side guy (fig. 2-8) is used to reinforce a pole line against an unbalanced side pull of the conductors. Such pulls are developed at curves, angles, or sharp turns in the line.

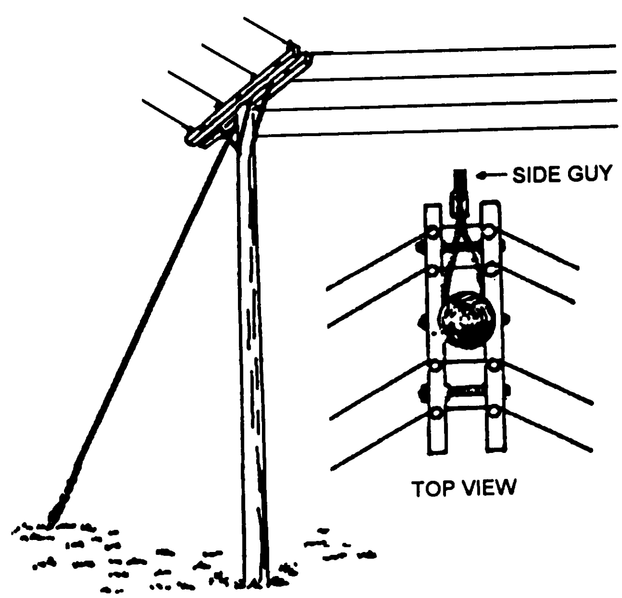

Figure 2-8.—Side guy.

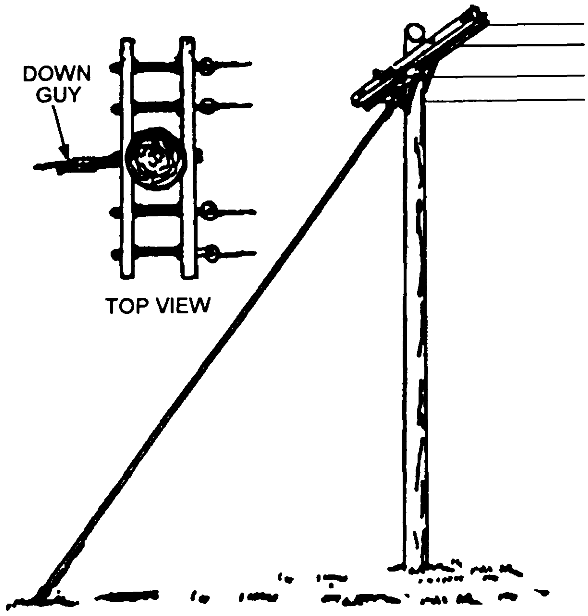

Figure 2-9.—Terminal down guy.

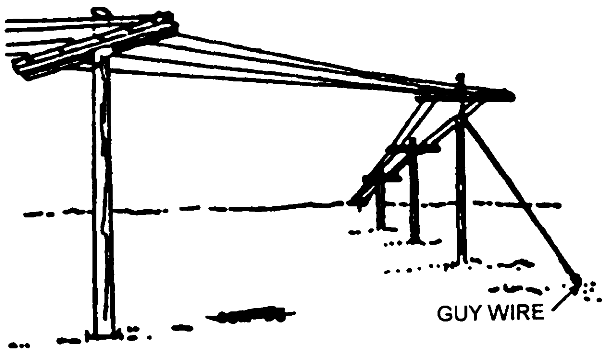

Figure 2-10.—Corner guy.

b. TERMINAL DOWN GUY. As shown in figure 2-9, this type of guy is usually placed at the end of a pole line to counterbalance the pull of the line conductors. The terminal down guy can, at times, be called a **corner guy.**

c. CORNER GUY. The corner guy (fig. 2-10) is used where there is a directional change in the line.

d. LINE GUY. A line guy is installed in a straight pole line where an unusual stress or strain comes from farther down the pole line or where there is a chance the conductors may break and cause excessive damage. Many times, line guys are installed in pairs, as shown in figure 2-11. A line guy is often called a storm guy.

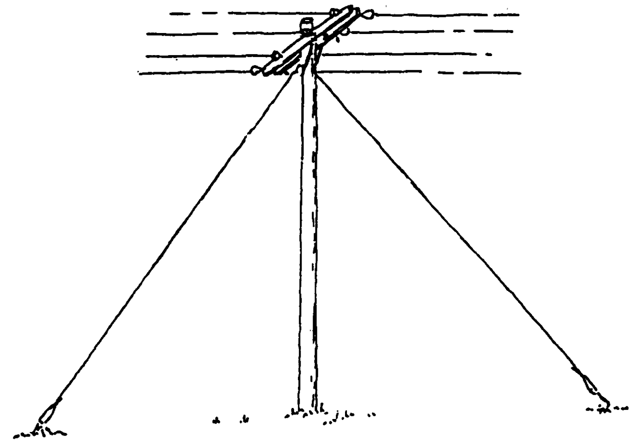

Figure 2-11.—Line guy, or storm guy.

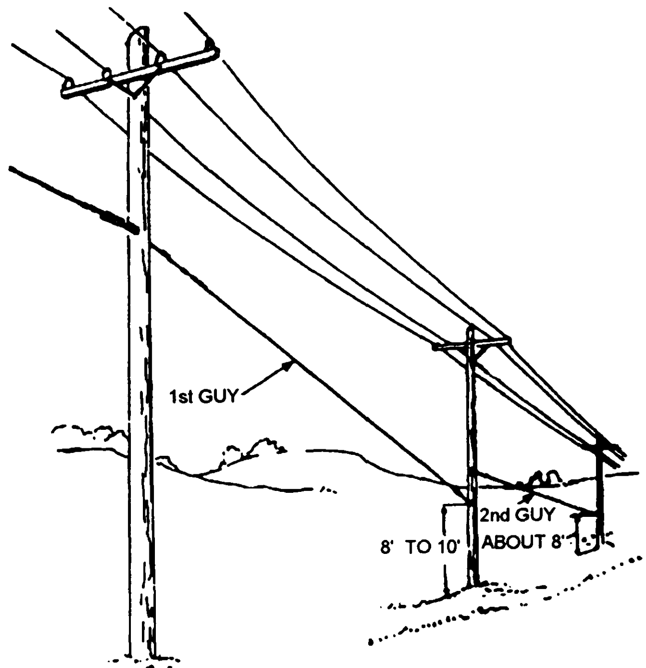

Figure 2-12.—Head guy.

2. HEAD GUY. A head guy runs from one pole to the next pole down the line. It is used to transfer the load supported by one line pole to another, as shown in figure 2-12.

3. PUSH BRACE. A push brace (fig. 2- 13) is used where a pole cannot be guyed and is too small to be self-sustaining. It is used in marshy or sandy soils where anchors cannot be firmly embedded. The upper end of the brace is bolted to the pole.

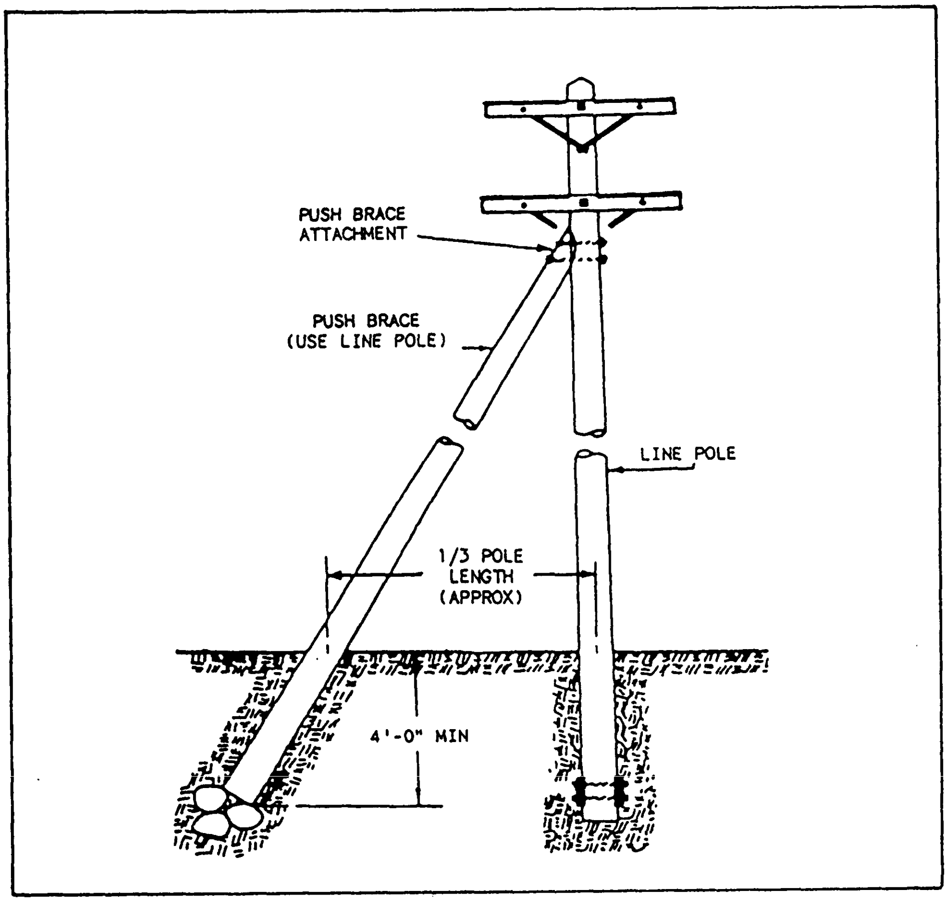

Figure 2-13.—Push brace.

Laying Out of Pole Lines

Pole lines are designed based on materials and construction methods specified in *Overhead Electrical Work,* NAVFAC NFGS-16302. The following paragraphs briefly describe some of the things that are considered when designing and constructing a pole line. As an EA preparing construction drawings or performing surveying operations, you may be directly involved in some of them. The following discussion is intended as familiarization so you will understand why the engineer plans a line the way he does:

1. **Use the shortest possible route.** Most of the time the shortest route is the least expensive. The pole line should be run as straight as possible from one point to another.

2. **Follow highways and roadways as much as possible.** This makes it easy to build the line and to inspect and maintain it. As much as possible, the pole line should be located on the same side of the road, and on the side that is most free of other lines and trees. When trees line the road, it might be better to locate the line a short distance away from the road. That way the trees are preserved, tree trimming is eliminated, there are no outages caused by trees falling into the line, and maintenance of the line is simplified.

3. **Follow the farmer's property or section lines.** This is normally not a major concern in the military. However, the engineer may have to consider bomb ranges and other such areas. If railroad tracks run through the area, it is best to follow them since the path has already been cut.

4. **Route in the direction of possible future loads.** The route of the pole line should go as close to new load centers as possible.

5. **Avoid going over hills, ridges, swamps, and bottom lands.** Hills and ridges are subject to lightning storms. Swamps and bottom lands are subject to

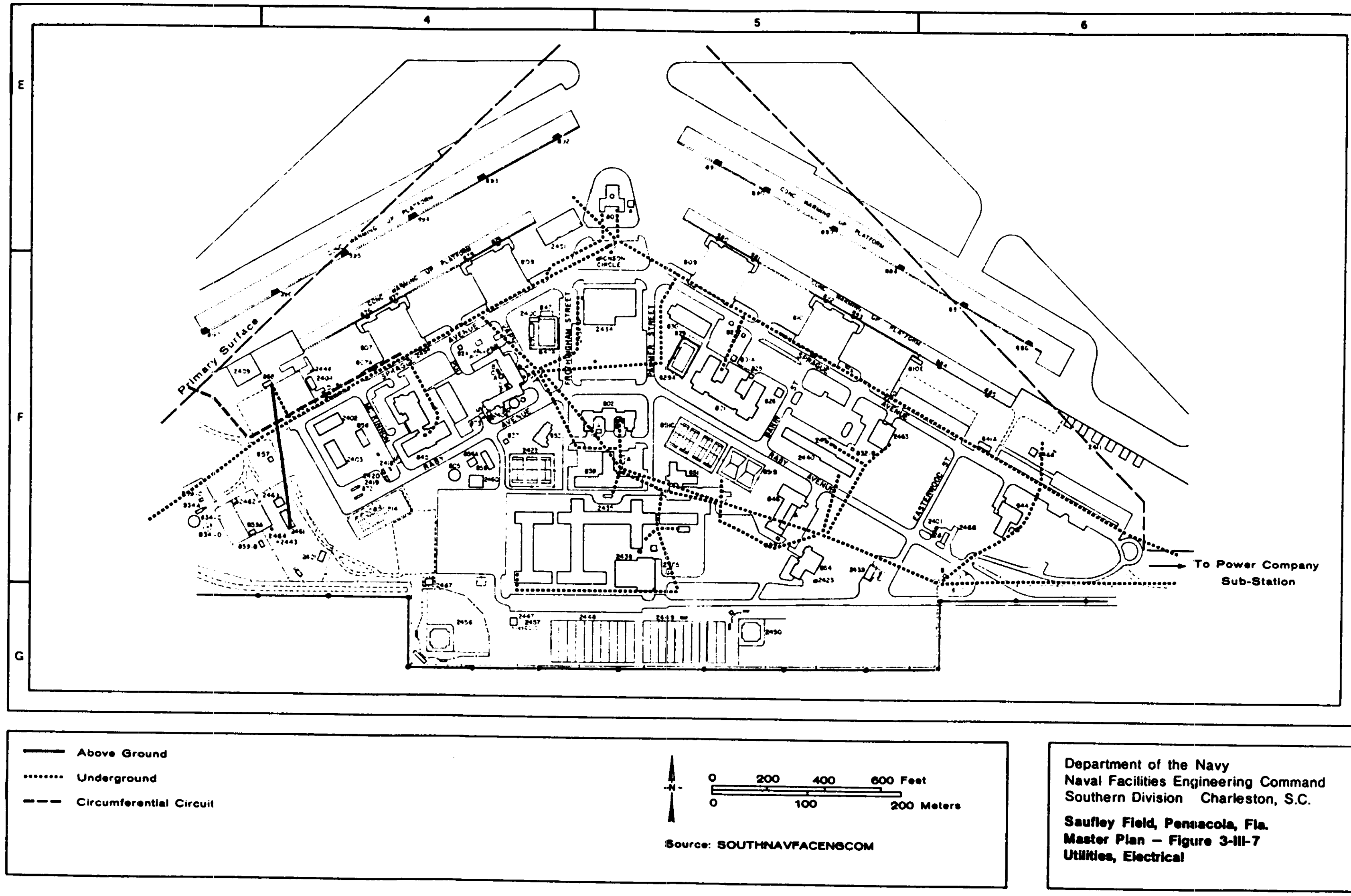

Figure 2-14.—Typical master plan drawing of an electrical distribution system.

flooding. Following these routes also makes it difficult to deliver materials.

6. **Avoid disrupting the environment.** Taking into consideration environmental codes and regulations, the engineer should select routes that cause the least disturbance to the environment. The engineer should also consider aesthetics when reviewing possible routes.

ELECTRICAL DISTRIBUTION DRAWINGS

The following text discusses the types of electrical distribution drawings that you may prepare when you are assisting the engineering officer in a construction battalion or when assigned to the engineering division of a public works department.

Electrical Distribution Plans

The type and extent of information placed on an electrical distribution plan depends on the purpose of the plan. Figure 2-14 is a distribution plan for a Navy activity that is taken from that activity's master plan. As you can see, it shows the routes of the distribution circuits, but it only identifies them as aboveground or belowground. For this plan, you would find a brief narrative description of the circuits located in the text of the master plan.

Obviously, a drawing of the type shown in figure 2-14 is of little use to an engineer or lineman who requires specific information about the distribution system. For this purpose, you should prepare a detailed electrical distribution plan. The detailed plan is drawn using the proper electrical symbols found in ANSI Y32.9. Similar to figure 2-14, the detailed plan shows all buildings and facilities and the routing of the distribution lines. In addition and as applicable to the type of system you are drawing, you also should include the following information:

1. The source of power (power plant, public utility line, substation, or standby generator with electrical data).

2. The number, type, and size of underground conduit or cable ducts and the size, number, voltage, and type of cable.

3. Where cable runs are made without installed ducts, indicate the location, dimensions, and description of splice boxes.

4. Identify and describe all electrical manholes and handholes by location, identification number, type, dimensions, and top and invert elevations.

5. Describe all transformer vaults, either aboveground or belowground, with dimensions, top and invert elevations, numbers, type, and electrical data.

6. Electrical data for all substations.

7. The location and type of all sectionalizing switches.

8. The number, size, type, and voltage of all overhead conductors.

9. The location, identification, material, class, and height of all poles.

10. The number and rating of all pole-mounted transformers.

11. Street-lighting systems, light standards, type, and rating of lights.

12. The number, size, voltage, and type of street-lighting circuits.

13. Note any buildings containing street-lighting transformers and control equipment together with type and rating of transformers.

To simplify the drawing, it is common practice to place much of the above information in appropriate schedules. For example, in an overhead distribution plan, you need only show the location and identification number of the poles on the plan. The material, class, and height of the poles can be placed in a pole schedule that is listed by the pole identification numbers.

Site Plans

Site plans are discussed in the EA3 TRAMAN. As you should recall from your study of that training manual, a site plan furnishes the essential data for laying out a proposed facility. It shows property boundaries, contours, roads, sidewalks, existing and proposed buildings or structures, references, and other significant physical features, such as existing utility lines. For small, uncomplicated buildings, you can often show all proposed electrical and other new utility lines on the same site plan. For the average facility, however, it is common practice to prepare separate utility plans that are included, as applicable, in the plumbing and electrical divisions of a set of project plans.

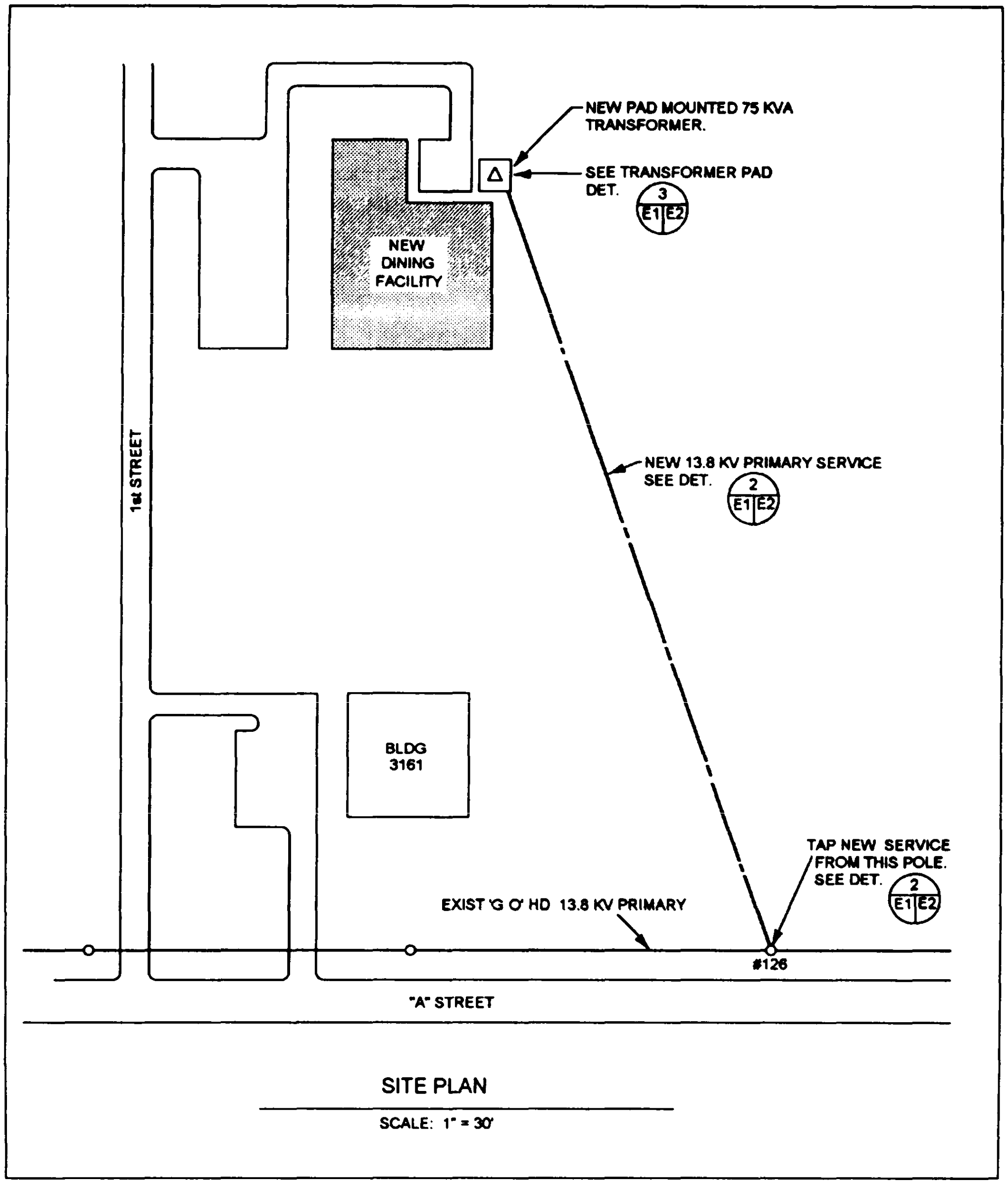

Figure 2-15.—Electrical site plan.

Figure 2-15 shows a simple electrical site plan. This plan shows the routing of a new 13.8-kilovolt (kV) primary service line to a new dining facility. The new service is tapped to an existing 13.8-kV overhead primary feeder, runs down existing pole Number 126, and then runs underground to a new pad-mounted 75-kilovoltampere (kVA) transformer located next to the new facility.

Although a competent Construction Electrician or contractor could install this new service line from only the site plan, as shown in figure 2-15, he would have to prepare additional drawings or sketches to show his workmen the specific details of the construction. Therefore, to provide a better description of the installation, the electrical designer prepares additional electrical details.

Electrical Details

The purpose of details is to leave little doubt about the exact requirements of a construction job. In preparing the details for the installation shown in figure 2-15, the designer chose to begin at the existing pole and work towards the new transformer pad. Figure 2-16 is a detail of the existing pole. This detail leaves little doubt about the requirements at the pole. For example, it shows the existing pole, crossarm, the existing 13.8-kV feeder, and required clearance distances. It also shows that the new circuit taps the existing conductors and then

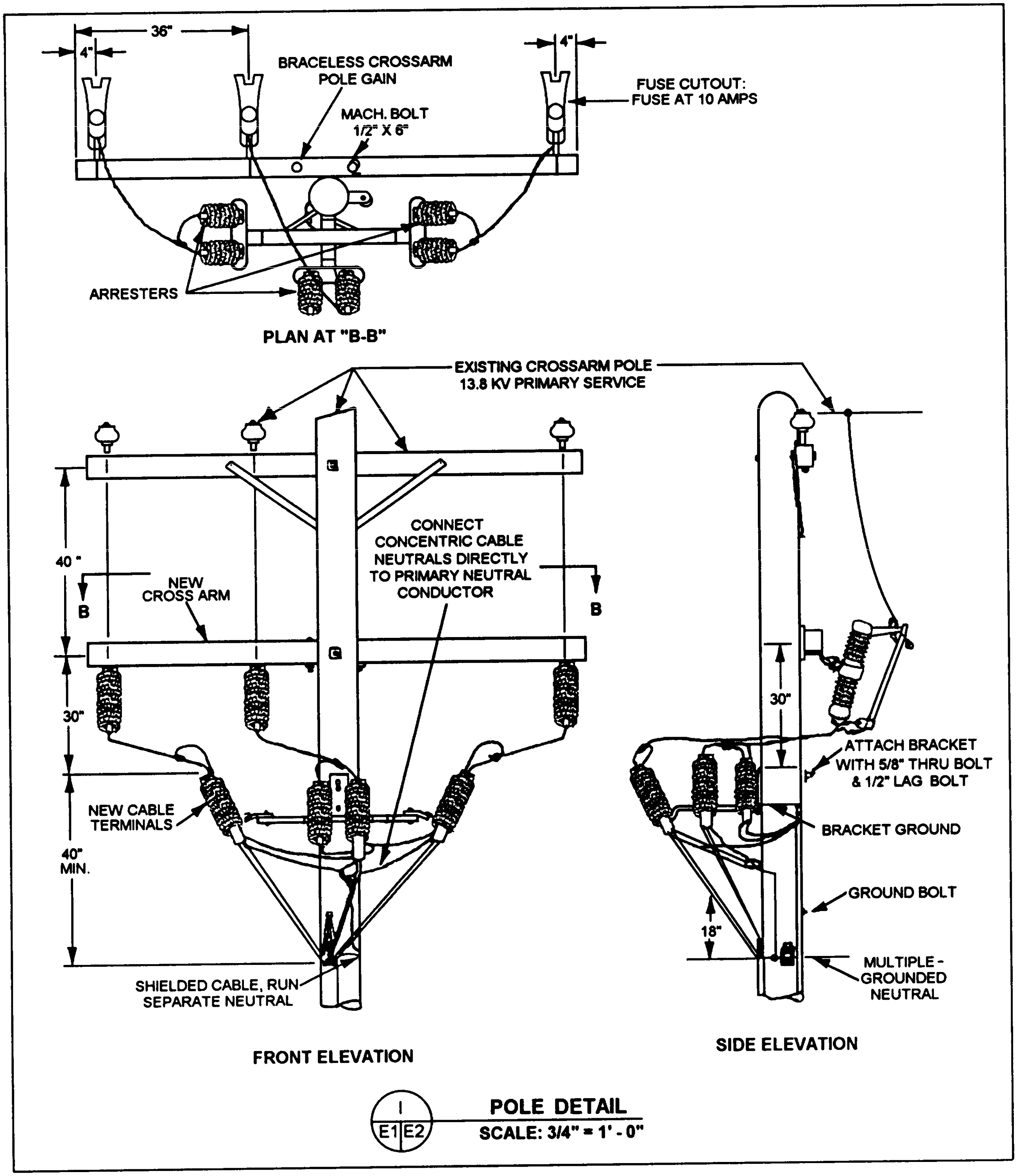

Figure 2-16.—Pole detail for use with the site plan shown in figure 2-15.

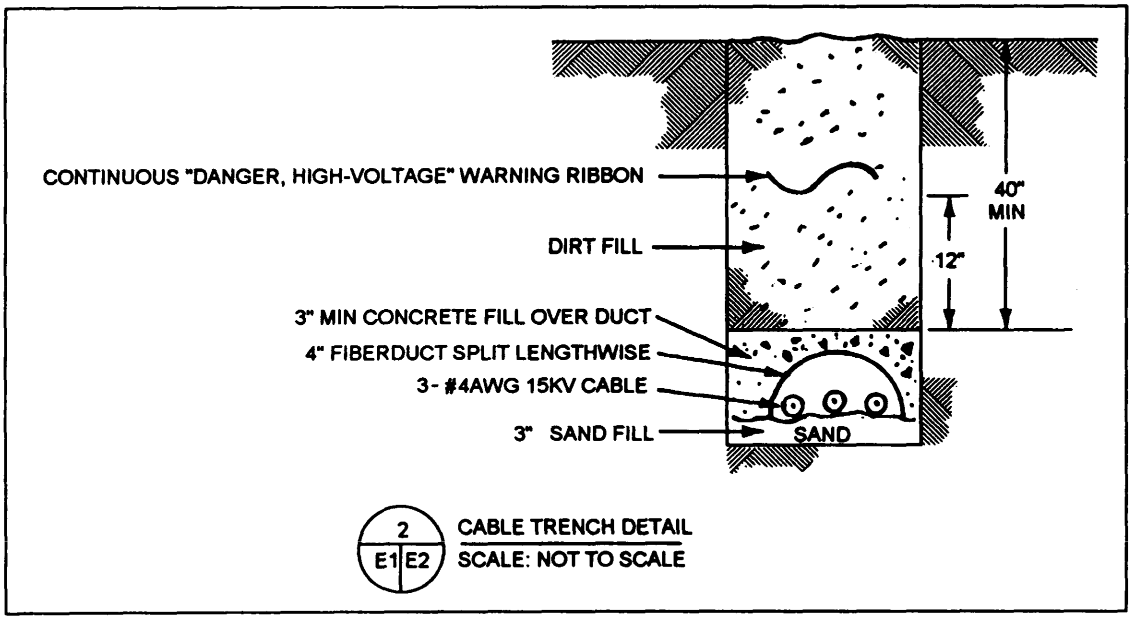

Figure 2-17.—Cable-trench detail for use with the site plan shown in Figure 2-15.

runs to three new 10-ampere fused cutouts before running to the new cable terminals and lightning arresters.

Figure 2-16 also shows that a new three-wire shielded cable is connected to the cable terminators and runs down the pole. From the pole, the cable is then run, as shown in figure 2-17, at a specified distance underground to the new transformer pad. Figure 2-18 is a detail of the pad that the designer included in the working drawings for the circuit installation. As you can see, these details leave little doubt about the job requirements. However, other information, such as specified material requirements for the concrete, cables, conduit, and so forth; specified procedures for backfilling the trench and placing the concrete; and any other information necessary to a fill understanding of the material and installation requirements should also be shown on the drawings or in the project specifications.

The preceding discussions of electrical transmission and distribution systems, distribution plans, and electrical details should leave you in a better position to aid the engineering officer or other design engineers. However, to increase your knowledge and to become even more valuable as an EA, you should further your studies by reading other publications, including the CE TRAMANs and commercial publications, such as *The Lineman's and Cableman's Handbook* by Kurtz and Shoemaker.

Now let us look at some other utility systems that you will be involved with.

WATER SUPPLY AND DISTRIBUTION

A water supply system consists of all the facilities, equipment, and piping that are used to obtain, treat, and transport water for a water distribution system. A distribution system is a combination of connected pipes that carry the supplied water to the users. In this section, we will discuss water distribution so you will be familiar with the elements of a distribution system and types of information that is required on distribution drawings. First,, however, we will discuss water sources and the need for water treatment. Although it is the engineer's responsibility to select a water source for use, to determine the methods of developing the source, and to design the supply and distribution system, you should have a general knowledge of this subject so you, as a technician, will be better able to assist the engineer.

WATER SOURCES AND TREATMENT

While the Navy prefers to obtain potable water from nearby public sources, it is sometimes not possible to do so. The following text briefly discusses the different types of water sources, source selection and develop ment, and the need for water treatment.

Water Sources

For most uses, the principal source of water is rain. This source is classified as **surface water** and **groundwater.**

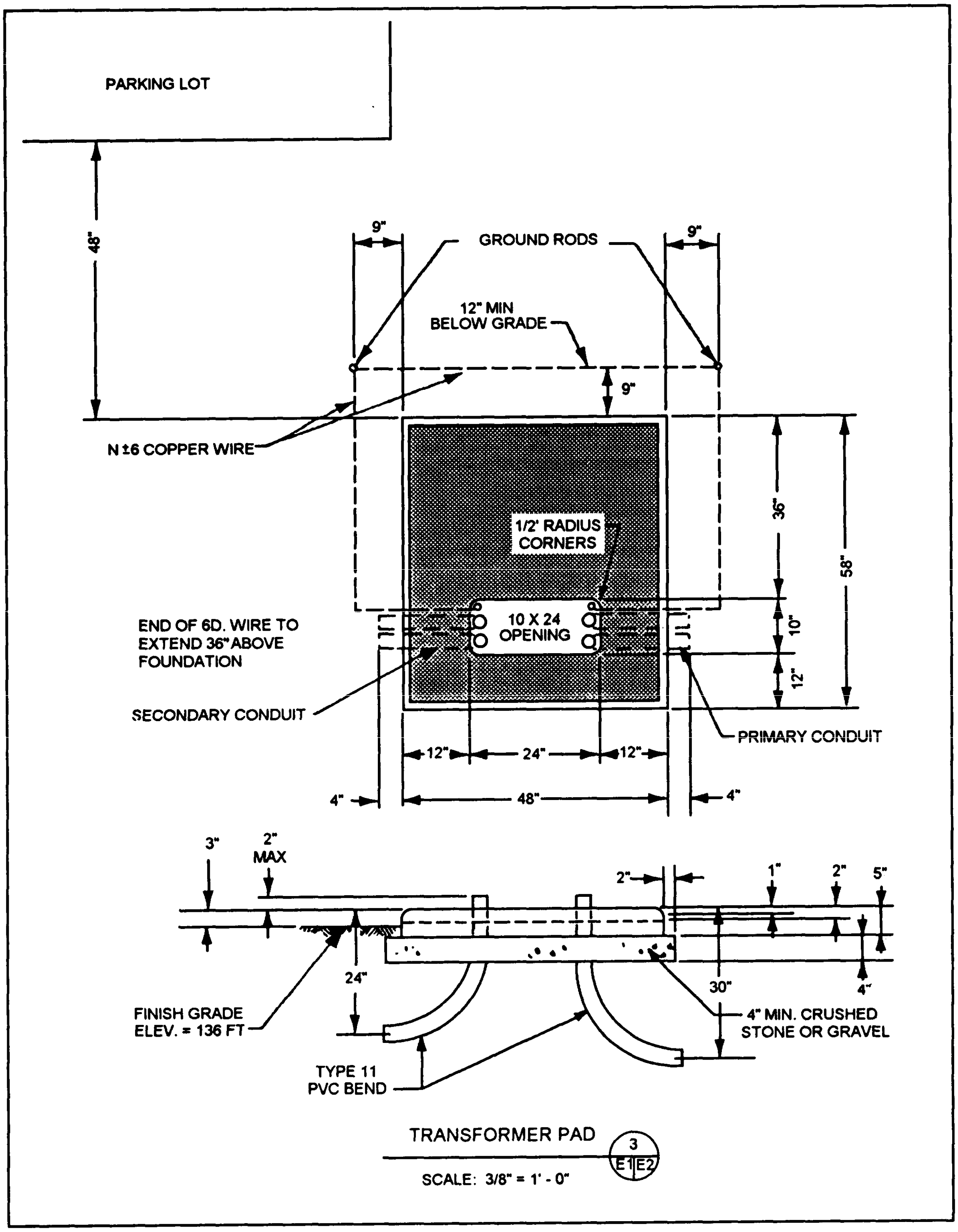

Figure 2-18.—Transformer pad details for use with the site plan shown in figure 2-15.

Surface water is rain that runs off the ground into streams, rivers, and lakes. It is the most common source used for a water supply. The availability of this source, though, depends on the amount of rainfall an area receives. In areas where there is substantial rain, the amount of surface water may be plentiful; but in dry areas or during a drought, the supply may be minimal or significantly reduced.

Groundwater is the water that percolates through the soil and builds up as underground sources. As groundwater seeps through the soil, it collects over an impervious stratum (a layer of earth, usually rock, that the water cannot penetrate) and forms a water level known as the **water table.** The depth of the water table-or the distance from the ground surface to the water level—varies considerably with the amount of rainfall. During droughts, the water table may be lowered, but during a rainy season it will probably rise.

As you should understand from your studies of soil formation, the stratum over which groundwater accumulates is an irregular, rather than a continuously flat, plane. Therefore, unless the water is confined, it flows horizontally over the irregular stratum and is nearer the surface in some places than it is in other places. Where this underground water flows near the surface and the ground area is low, the water may flow out as a spring. Or, it may seep out and create a swampy area. The underground, flowing water also may become entrapped between impervious layers. In this case, enough water pressure may buildup to create an artesian well if the strata is penetrated by drilling or by a natural opening.

In some regions of the world, there is not enough surface water or groundwater available to support the need for water. In these areas alternative sources are necessary. Rain, itself, can be an alternative source. In some locations, large catchment areas are constructed to collect rain and store it for future use. These catchment areas are usually constructed on the side of a mountain or a hill facing the prevailing direction of rainfall. In other areas, snow and ice may be used as alternative sources. Another source, although costly to develop for use, is seawater that has had the salt removed by desalination.

Selection and Development of Water Sources

When selecting a water source for development, the engineer must consider three primary factors: water quantity, water reliability, and water quality.

The quantity factor considers the amount of water that is available at the source and the amount of water that will be required or demanded for use. The amount of water that maybe available at the source depends on variables, such as the amount of precipitation, the size of the drained area, geology, ground surface, evaporation, temperature, topography, and artificial controls. Water demands are estimated using per capita requirements and other controlling factors, such as water requirements for fire protection, industrial use, lawn sprinkling, construction, vehicles, and water delivered to other activities.

The reliability of a water supply is one of the most important factors that the engineer considers when selecting a water source. A reliable water source is one that will supply the required amount of water for as long as needed. To determine the reliability of the water source, the engineer studies data, such as hydrological data, to determine the variations that maybe expected at the water source. Geological data should be studied since geological formations can limit the quantity and flow of water available. Also, legal advice may be necessary when selecting a water source since the laws regulating and controlling water rights may vary considerably from state to state and country to country.

The third primary factor the engineer must consider when selecting a water source is the quality of the water. Practically all water supplies have been exposed to pollution of some kind. Therefore, to ensure that water is potable and palatable, it must be tested to determine the existence of any impurities that could cause disease, odor, foul taste, or bad color. In most cases, the water will require treatment for the removal of these impurities. In water treatment, the water is subjected to various filtration and sedimentation processes, and in nearly all cases is disinfected using chlorine or other disinfecting chemicals.

Once the water source has been selected, development of the source can begin. Developing a water source includes all work that increases the quantity and improves the quality of the water or makes it more readily available for treatment and distribution. In developing a source, the engineer may use the construction of dams, digging or drilling of wells, and other improvements to increase the quantity and quality of the water.

For a more detailed discussion of water source selection, development, and treatment, you should refer to chapter 9 of the UT1 TRAMAN. For NAVFAC guidance, you should refer to *Water Supply System,* MIL-HDBK-1005/7.

Now that you are familiar with water sources, let us move onto water distribution.

DISTRIBUTION SYSTEM ELEMENTS AND ACCESSORIES

The elements of a water distribution system include distribution mains, arterial mains, storage reservoirs, and system accessories. These elements and accessories are described as follows:

1. DISTRIBUTION MAINS. Distribution mains are the pipelines that make up the distribution system. Their function is to carry water from the water source or treatment works to users.

2. ARTERIAL MAINS. Arterial mains are distribution mains of large size. They are interconnected with smaller distribution mains to form a complete gridiron system.

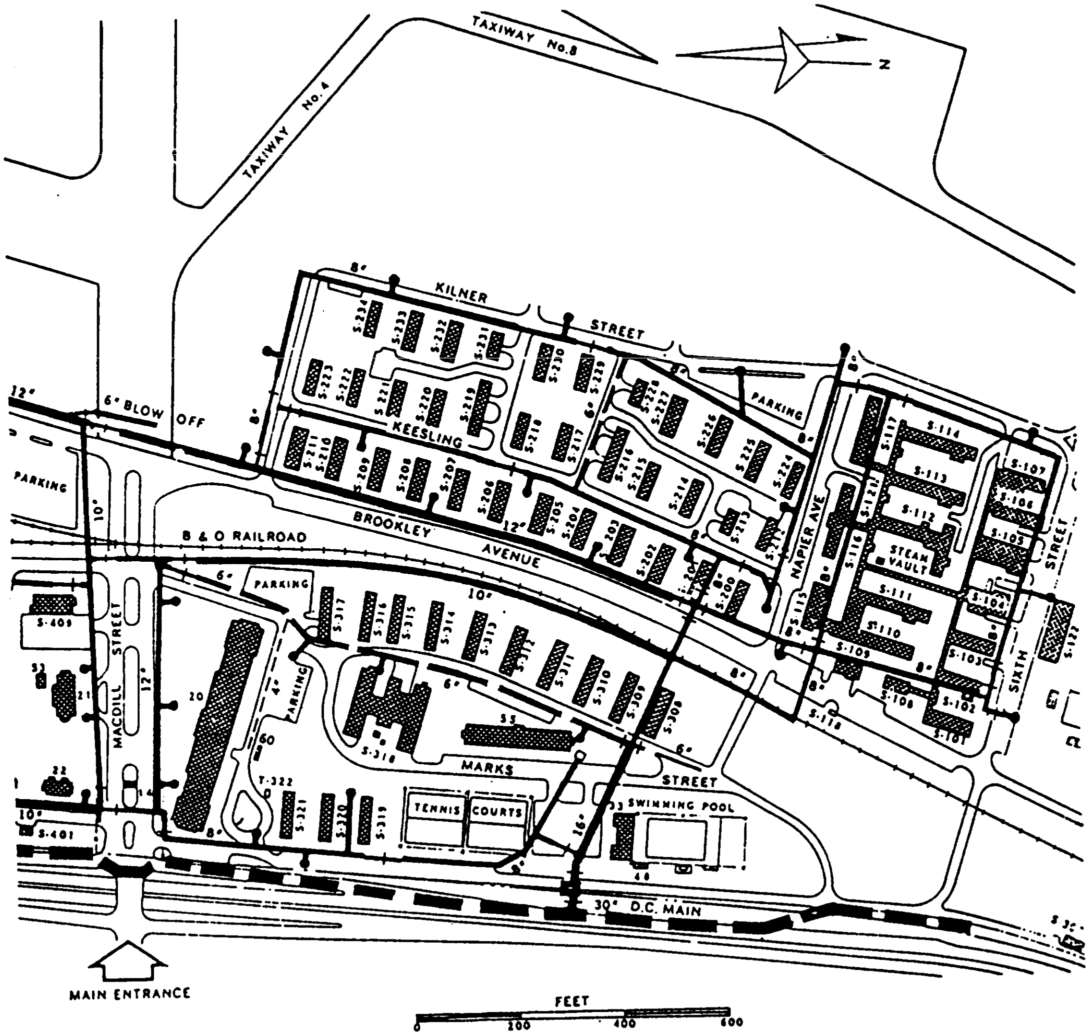

Figure 2-19.—Typical distribution system layout.

3. STORAGE RESERVOIRS. Storage reservoirs are structures used to store water. They also equalize the supply or pressure in the distribution system. A common example of a storage reservoir is an aboveground water storage tank.

4. SYSTEM ACCESSORIES. System accessories include the following:

a. BOOSTER STATIONS. Booster stations are used to increase water pressure from storage tanks or low-pressure mains.

b. VALVES. Valves control the flow of water in the distribution system by isolating areas for repair or by regulating system flow or pressure.

c. HYDRANTS. Hydrants are designed to allow water from the distribution system to be used for fire-fighting purposes.

d. METERS. Meters record the flow of water in a part of the distribution system.

e. SERVICE CONNECTIONS. Service connections are used to connect individual buildings or other plumbing systems to the distribution system mains.

f. BACKFLOW PREVENTERS. A **cross-connection** is any connection between a potable and nonpotable water system through which a contaminating flow can occur. Backflow preventers, such as air gaps and vacuum breakers, are used to prevent flow through potential cross-connections.

DISTRIBUTION SYSTEM LAYOUT

When distribution systems are carefully planned, the pipes are usually laid out in a grid or belt system. A network of large pipes divides the community or base into areas of several blocks each (fig. 2-19). The streets within each area are served by smaller pipes connected to the larger ones. If possible, the network is planned so the whole pipe system consists of loops, and no pipes come to a dead end. In this way, water can flow to any point in the system from two or more directions. This eliminates the need to cut off the water supply for maintenance work or to repair breaks.

Older water systems frequently were expanded without planning and developed into a treelike system. This consists of a single main that decreases in size as it leaves the source and progresses through the area originally served. Smaller pipelines branch off the main and divide again, much like the trunk and branches of a tree. A treelike system is not desirable because the size of the old main limits the expansion of the system needed to meet increasing demands. Also, there are many dead ends in the system where water remains for long periods, causing undesirable tastes and odors in nearby service lines.

MIL-HDBK-1005/7 provides specific guidance to follow when planning the location of mains. In general, mains should be located so they are clear of other structures and should be adjacent and parallel to streets but not within roadways, if possible. Mains also should be separated from other utilities to ensure the safety of potable water and to lessen interference with other utilities during maintenance.

VALVE LOCATIONS

The purpose of installing shutoff valves in water mains at various locations within the distribution system is to allow sections of the system to be taken out of service for repairs or maintenance without significantly curtailing service over large areas. Valves should be installed at intervals not greater than 5,000 feet in long supply lines and 1,500 foot in main distribution loops or feeders. All branch mains connecting to feeder mains or feeder loops should have valves installed as close to the feeders as practical. In this way, branch mains can be taken out of service without interrupting the supply to other locations. In the areas of greatest water demand or when the dependability of the distribution system is particularly important, valve spacing of 500 feet maybe appropriate.

At intersections of distribution mains, the number of valves required is normally one less than the number of radiating mains. The valve omitted from the line is usually the one that principally supplies flow to the intersection As for as practical, shutoff valves should be installed in standardized locations (that is, the northeast comer of intersections or a certain distance from the center line of streets), so they can be easily found in emergencies. All buried small- and medium-sized valves should be installed in valve boxes. For large shutoff valves (about 30 inches in diameter and larger), it may be necessary to surround the valve operator or entire valve within a vault or manhole to allow repair or replacement.

HYDRANT LOCATIONS

Criteria for fire hydrants are found in *Fire Protection for Facilities Engineering, Design, and Construction,* MIL-HDBK-1008A. Street intersections are the preferred locations for fire hydrants because fire hoses can be laid along any of the radiating streets. Hydrants should be located a minimum of 6 feet and a maximum of 7 feet from the edge of paved roadway surfaces. If they are located more than 7 feet from the edge of a road, then ground stabilizing or paving next to the hydrants may be necessary to accommodate fire-fighting equipment.

Hydrants should not be placed closer than 3 feet to any obstruction and never in front of entranceways. In general, hydrants should be at least 50 feet from a building and never closer than 25 feet to a building, except where building walls are blank fire walls.

GENERAL REQUIREMENTS FOR WATER DISTRIBUTION DRAWINGS

The following text provides general information on the contents of water distribution plans and details.

Plans

The MINIMUM information that you should show on a water distribution plan is listed as follows:

1. Locations and lengths of mains

2. Sizes and types of piping materials

3. Locations, sizes, and types of all valves

4. Location of fire hydrants; meter pits; outlets on piers; elevated, ground, or underground water storage reservoirs; water wells; pump houses; and valve boxes, vaults, and manholes

5. Capacities and heads of all water pumps in pump houses, including minimum average and maximum residual pressures at points of connection to municipal water systems

6. Exterior sprinklers or fire mains, including indicator and main shutoff valves

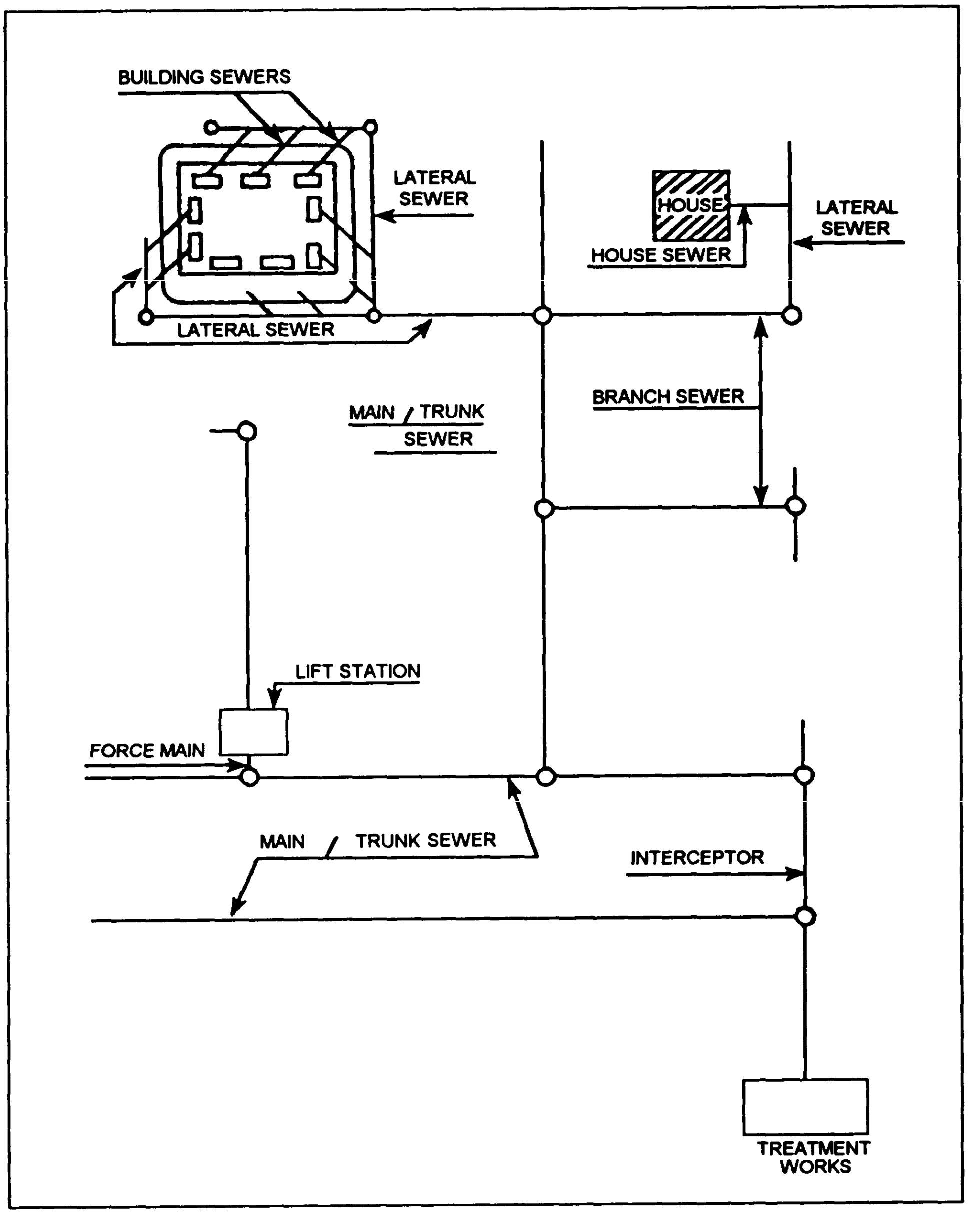

Figure 2-20.—Diagram of a wastewater collection system.

Details

Details that should be included in a set of construction drawings of a water distribution system are varied and numerous. You may, for example, prepare plans, elevations, and details for a new water storage tank. Other examples are as follows: thrust block details, trench details for underground piping, details for aboveground pipe supports, and plans and details for valve boxes, vaults, and so forth. The design engineer will determine the details to be shown.

WASTEWATER SYSTEMS

In addition to drawings of electrical and water distribution systems, you may be required to prepare detailed drawings of wastewater systems. This section provides a brief overview of these systems so you will be familiar with the elements and structures used in wastewater systems and the general content requirements for wastewater system drawings.

SYSTEM ELEMENTS AND STRUCTURES

A wastewater system (fig. 2-20) consists of the collection of sewer pipes and pumps that are designed

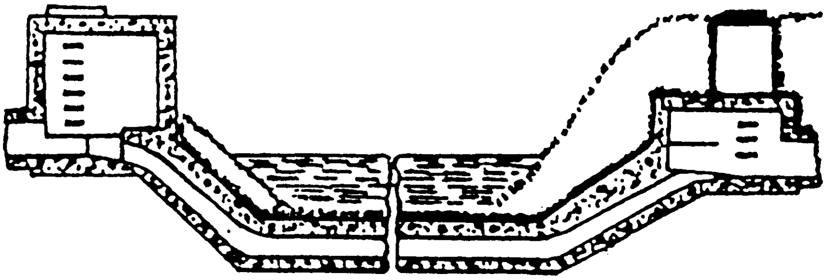

Figure 2-21.—An inverted siphon.

to convey domestic and industrial wastes and to transport them to a wastewater treatment plant. The purpose of these systems is to safeguard public health by preventing disease-producing bacteria, viruses, and parasites getting into groundwater or drinking water systems. A description of the various elements and structures used in a wastewater system is as follows:

1. SANITARY SEWER. A sanitary sewer system carries mostly domestic wastes but may carry some industrial waste. These systems are NEVER designed to carry storm water or groundwater. (To convey storm water, groundwater, or other surface water to disposal points, a **storm sewer** system is designed and constructed separately from the sanitary sewer system.) Sanitary sewer system piping includes the following:

a. BUILDING, OR HOUSE, SEWER. A service-connection pipe that connects an individual building to the wastewater system. These pipes are 4 inches or larger in diameter and are commonly concrete, cast iron, or plastic. The building, or house, sewer is the smallest pipe in a wastewater collection system. All other pipes must be a MINIMUM of 8 inches in diameter.

b. LATERAL SEWER. Piping that receives discharge from house sewers.

c. SUBMAIN, OR BRANCH, SEWER. A pipe that receives waste from two or more lateral sewers.

d. MAIN, OR TRUNK, SEWER. A pipe that takes discharge from two or more submains or from a submain plus laterals.

e. INTERCEPTING SEWER. One that receives wastewater from more than one main, or trunk sewer.

f. RELIEF SEWER. A sewer built to relieve an existing sewer that has an inadequate capacity.

2. LIFT STATION. Most piping in a wastewater system consists of gravity pipes that are designed to flow by gravity action at a rate of not less that 2 feet per second. Where gravity flow is not practical or possible, a lift station, such as the one shown in figure 2-20, is constructed to pump wastewater to a higher level. From the lift station, the wastewater is pumped through a pipe, called a **force main, to** higher elevation gravity pipes. Unlike gravity piping, force mains always flow complete] y filled and under pressure.

3. INVERTED SIPHON. Another sewer pipe designed to flow full and under pressure is the inverted siphon. These pipes dip below the designed gradient of the gravity pipes and are used to avoid obstacles, such as open-cut railways, subways, and streams. An example of an inverted siphon is shown in figure 2-21. The inverted siphon may have one, two, or more pipes and is designed to flow at a rate of at least 3 feet per second to keep the pipe(s) clear of settleable solids. It should have manholes constructed at both ends for maintenance.

4. MANHOLE. A manhole is a concrete or masonry structure used for inspection and maintenance of sewer lines. Examples of manholes are shown in figure 2-22. The bottom portion of a manhole is usually cylindrical and has an inside diameter of at least 4 feet. The upper portion usually tapers to the street or ground surface and is fitted with a cast-iron cover. For proper sewage flow, the bottom of the manhole slopes toward a built-in charnel that has a depth of three fourths of the diameter of the sewer pipe. For sewers up to approximate] y 60 inches in diameter, manholes are usually spaced 300 to 400 feet apart. They are also required at all locations where sewer lines intersect or where the sewer lines change direction, grade, or pipe size.

DESIGN

Design guidance for wastewater systems is contained in *Domestic Wastewater Control,* MIL-HDBK-1005/8.

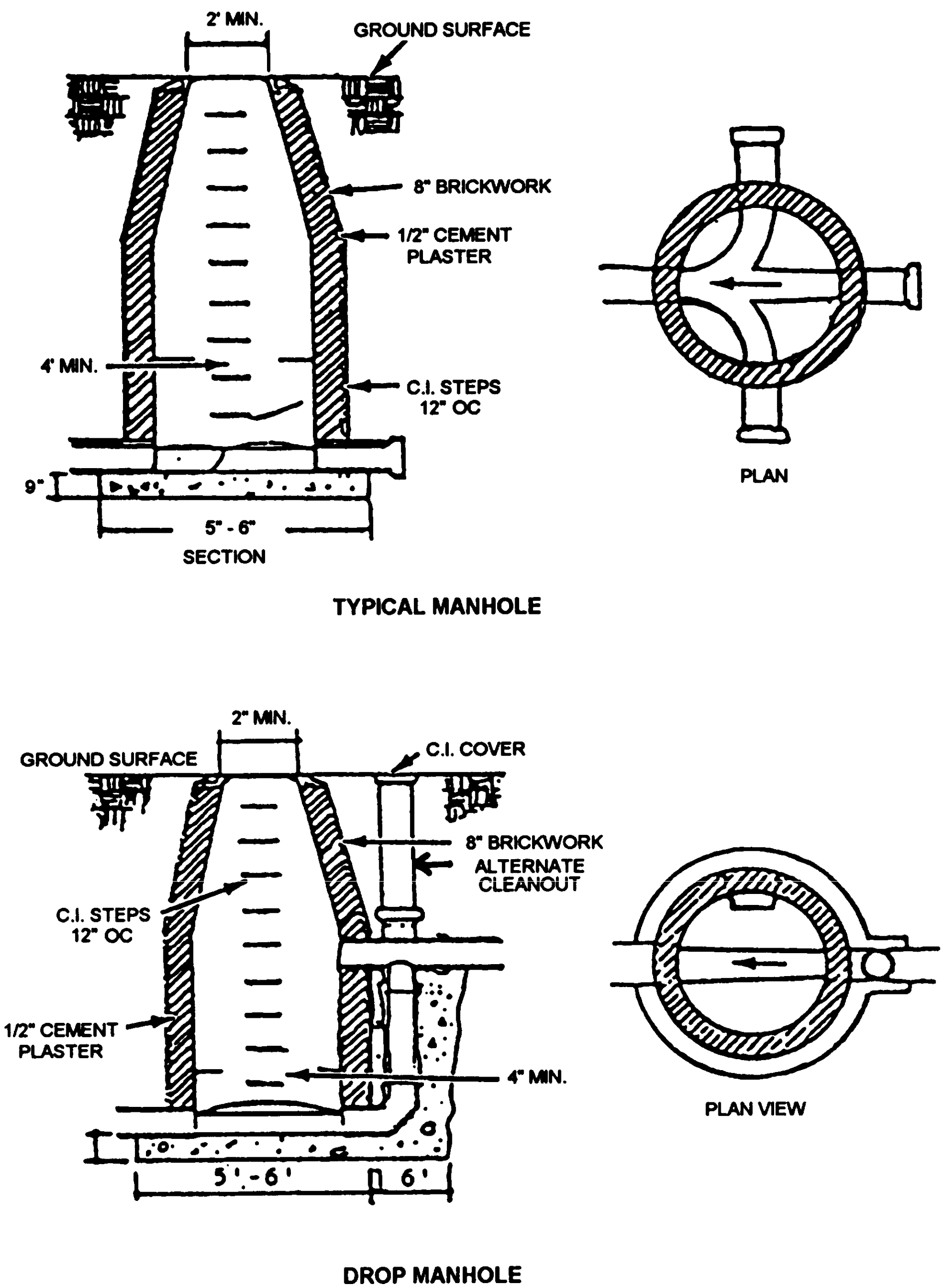

Figure 2-22.—Types of manholes

When designing a wastewater system, the design engineer begins by first determining the types and quantities of sewage to rehandled. This is accomplished through a careful study of the area to be served. The design engineer bases his design on the average daily use of water per person in the area to be served. A typical value is 100 gallons per person per day. But, the use of water is not constant. Use is greater in the summer than in the winter and greater during the morning and evening than it is in the middle of the day or at night. Therefore, the average daily flow (based on the average utilization) is multiplied by a peak flow factor to obtain the design flow.

Typical peak flow factors range from 4 to 6 for small areas down to 1.5 to 2.5 for larger areas. An allowance for unavoidable infiltration of surface and subsurface water into the lines is sometimes added to the peak flow to obtain the design flow. A typical infiltration allowance is 500 gallons per inch of pipe diameter per mile of sewer per day. From the types of sewage and the estimated design flow, the engineer can then tentative] y select the types, sizes, slopes, and distances below grade of the piping to be used for the system.

Then preliminary drawings of the system are prepared. The preliminary drawings should include both plans and profiles of the proposed wastewater system and all buildings, roads, waterways, utilities, geology, and so forth, that may affect the design. As an EA, you may be called upon to assist in the preparation of the preliminary plans. When existing topographic maps of sufficient detail are available, they may be used in selecting the routing of the proposed system. However, when existing maps are not available or to ensure sufficient detail, you may be required to conduct topographic and preliminary route surveying upon which the routing will be based. The procedures for these surveys are explained in chapters 8 through 10 of this manual.

Upon acceptance of the preliminary designs, final design may begin. During this phase, adjustments to the preliminary design should be made as necessary, based upon additional surveys, soil analysis, or other design factors. The final designs should include a general map of the area that shows the locations of all sewer lines and structures. They also should include detailed plans and profiles of the sewers showing ground elevations, pipe sizes and slopes, and the locations of any appurtenances and structures, such as manholes and lift stations. Construction plans and details are also included for those appurtenances and structures.

QUESTIONS

Q1. Name the two systems that comprise an overall power system.

Q2. What system of arranging primary feeders is the least reliable but the most commonly used?

Q3. What is the purpose of a distribution transformer?

Q4. In relation to the primary mains, where on a power distribution pole should the secondaris be located?

Q5. Under what circumstances are concrete power distribution poles authorized for use on a Navy installation?

Q6. On a drawing of an overhead electrical distribution system what information should you show for the overhead conductors?

Q7. Define water table.

Q8. What three primary factors must an engineer consider when selecting a water source?

Q9. When, if ever, is it permissible to install a water line and a sanitary sewer line in the same trench?

Q10. In a waste water system, what is the purpose of a lift station?